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Method for the internal combustion of a mixture of materials in a piston-driven internal combustion engine, and internal combustion engine for putting this method into practice

Patent Claims

1. The invention relates to a method for the internal combustion of a mixture of materials within a piston-driven internal combustion engine with which negative pressure is produced in the combustion chamber during a charging movement of the piston which enlarges the combustion chamber, the latter being charged with at least one gaseous component of the mixture of materials, the mixture of materials being compressed, ignited and expanded for the power output of the piston upon a movement of the piston in the opposite direction to the aforementioned movement, by which method the charge quantity of the gaseous component and/or the quantity of a liquid or gaseous second component of the same preferably provided as the energy source for the mixture of materials is controlled dependent upon the engine output, <u>characterized in that</u> additional measures are taken to substantially reduce the charge quantity of the gaseous first component of the mixture of materials, independently of the power control.

2. The method according to Claim 1, characterized in that measures are taken by means of which on the charging movement of the piston an additional negative pressure is produced which is essentially restricted to the combustion chamber only.

3. The method according to Claim 1 or 2, characterized in that an additional negative pressure reducing the charge is produced by closing a blocking component disposed in the region of the inlet port through which the gaseous first component enters the combustion chamber.

4. The method according to Claim 3, characterized in that with an engine with control components for controlling the gas exchange according to the working cycles, the control component allocated to the inlet port is used as the blocking component to produce the additional negative pressure.

5. The method according to Claim 4, characterized in that with an engine with a controllable inlet valve, this valve is maintained in the closure position closing the inlet port during a considerable proportion of the charging movement of the piston in order to produce the additional negative pressure.

6. The method according to Claim 5, characterized in that with a reciprocating piston engine, the inlet valve for the charging stroke is already closed well before reaching the bottom dead center of the piston allocated to the end of the charging stroke.

7. The method according to Claim 5, characterized in that with a reciprocating piston engine, the inlet valve is not opened until well past the top dead center allocated to the start of the charging stroke.

8. The method according to Claim 6 or 7, characterized in that the inlet valve is closed at a rotation angle of the crankshaft of less than $n \cdot 10°$ [= n times 10°] past the top dead center allocated to the start of the charging stroke of the piston - where n represents a integer from one to seventeen.

9. The method according to Claim 8, characterized in that the inlet valve is closed at a rotation angle of the crankshaft of less than 120° past the top dead center, and preferably of less than 90° past the top dead center.

10. The method according to Claim 2, characterized in that the additional negative pressure is produced by a choke device disposed in the gas supply shortly before the inlet port of the combustion chamber.

11. The method according to Claim 10, characterized in that a controllable choke device is used, and that the throttling effect of the same is preferably controlled dependent upon the number of revolutions.

12. The method according to Claim 1, characterized in that with a reciprocating piston engine with which air is compressed in the combustion chamber as the gaseous first component of the mixture of materials, a proportion of the air is blown off from the combustion chamber during the compression movement of the piston as an additional measure for reducing the charge quantity.

13. A piston-driven internal combustion engine for putting the method into practice according to any of Claims 1 to 12, with a device provided for controlling the engine power by influencing the charge quantity of the gaseous first component of the mixture of materials which can be supplied to the combustion chamber by the charging movement of the piston, characterized by a limiting device significantly reducing the charge quantity independently of the power control.

14. The engine according to Claim 13, characterized in that as a limiting device, a device is provided which produces additional negative pressure in the combustion chamber (21) during the charging movement of the piston (15).

15. The engine according to Claim 14, characterized in that the limiting device has a controllable blocking component in the region of the inlet port of the combustion chamber (21) which can be moved to the closure position for a substantial proportion of the charging movement of the piston (15).

16. The engine according to Claim 15, characterized in that with an engine with an inlet valve (19) serving to control the gas exchange, actuated by means of a valve control, this valve is provided as the blocking component for producing the additional negative pressure and can be controlled into the closure position by the valve control for a substantial proportion of the filling movement of the piston (15).

17. The engine according to Claim 13, characterized in that the limiting device has a throttle device (43, 45) which is disposed closely adjacent to the inlet port in the suction tube serving to supply the gaseous first component.

18. The engine according to Claim 17, characterized in that a controllable throttle device in the form of a throttle valve (45), a rotary valve or throttle flap [or butterfly valve] is provided.

19. The engine according to Claim 18, characterized in that with an engine with an inlet valve (19) serving to control the gas exchange and actuated by a valve control, this valve is provided as a throttle device and can be actuated by the valve control with only a small opening stroke, preferably changeable dependent upon the number of revolutions.

20. The engine according to Claim 13, characterized in that with an engine with which air is compressed in the combustion chamber (21) as the gaseous first component of the mixture of materials, a limiting device is provided to enable air to be blown off from the combustion chamber (21) during the compression movement of the piston (15).

21. The engine according to Claim 20, characterized in that with an engine with an outlet valve (20) serving to control the gas exchange and actuated by means of a valve control, this valve is provided as the limiting device for blowing off compressed air and can be moved into the open position by the valve control during a proportion of the compression movement of the piston (15).

22. The engine according to Claim 20, characterized in that with a two-stroke reciprocating piston engine, a blow-off valve (53) controllable according to the working cycle is provided, by means of which air can be blown off during the compression stroke of the piston (15).

23. The engine according to Claim 22, characterized in that the blow-off valve (53) opens out into the compression chamber (21) with a slit opening (55) over which the piston (15) can pass, disposed such that it is closed off by the piston (15) during the compression stroke before it reaches the top dead center of the piston.

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Method for the internal combustion of a mixture of materials in a piston-driven internal combustion engine, and internal combustion engine for putting this method into practice

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The invention relates to a method for the internal combustion of a mixture of materials within a piston-driven internal combustion engine with which negative pressure is produced in the combustion chamber during the charging movement of the piston which enlarges the combustion chamber, the latter being charged with at least one gaseous component of the mixture of materials, the mixture of materials being compressed, ignited and expanded for the power output of the piston upon a movement of the piston in the opposite direction to the aforementioned movement, by which method the charge quantity of the gaseous component and/or the quantity of a liquid or gaseous second component of the same preferably provided as the energy source for the mixture of materials is controlled dependent upon the engine output. Moreover, the invention relates to an internal combustion engine for putting this method into practice.

Given the worldwide application of this kind of method for the operation of internal combustion engines, it is known that to strive for the highest possible efficiency, i.e. the best possible exploitation of the fuel provided as an energy source, is of paramount economic importance, especially since the reserves of suitable energy sources are limited. Hence it is usual to design and to operate

internal combustion engines in such a way that the external engine losses, i.e. the energy dissipated through friction, the operation of auxiliary systems etc., are kept to the minimum possible, and also to provide the highest possible thermal efficiency of the combustion process. It is attempted to achieve improvement of the thermal efficiency for example by using components which can be subjected to higher temperatures, and which should make it possible to operate the engine reliably with lower heat energy losses via the cooling system. It is also known to increase the thermal efficiency by increasing the compression ratio. A better efficiency is produced here, among other things, because with a greater compression ratio, the particles of the mixture of materials are pressed closer together during the compression movement of the piston and become hotter, giving a better mixture of the first, gaseous component with the second component provided as an energy source, in particular where this is a liquid energy source, the fuel droplets of which are thereby extensively gasified, by means of which the combustion is more rapid and complete. Moreover, the smaller combustion space associated with the greater compression ratio has a smaller cooling surface area such that the heat loss through the engine walls to the cooling system is correspondingly less.

However, the known measures for improving thermal efficiency are subject to relatively narrow limits. In attempting to lose as little heat as possible via the cooling system, even if components with high thermal tolerance are used, it is found that the stability of the engine during operation suffers. Increasing the compression ratio likewise has its limits. For example, in an Otto engine there is an upper limit on the compression ratio determined by the need for the engine to run without "pinging" [or pinking or knocking]. In a Diesel engine there is a corresponding limitation imposed by the need not to impose excessively high tolerances on the component parts, the lighter and cheaper construction of the engine and the avoidance of excessively rough running.

The object underlying the invention is to provide a combustion process of the type in question, the use of which makes it possible to achieve an additional

improvement of the efficiency which far outstrips that achievable with the conventional methods.

This objective is attained according to the invention with a method of the type specified at the start in that additional measures are taken to substantially reduce the charge quantity of the gaseous first component of the mixture of materials, independently of the power control. The general idea behind this method is to design the combustion method such that the burning mixture of materials can be expanded far more completely within the combustion chamber than is possible with conventional methods. By operating, in accordance with the invention, with an extremely small charge, a larger expansion volume (corresponding to the cylinder capacity) is available within the combustion chamber in relation to the charge quantity, i.e. the volume of the charge, i.e. it is made possible for the burning mixture of materials to expand more strongly during the activity release. The reduction of the charge quantity volume, i.e. the enlarging of the expansion volume, or cylinder capacity, in relation to the charge quantity, brings about more complete energy conversion within the system due to better exploitation of the expansion.. The energy content of the more strongly relaxed, and hence cooler, exhaust gas is less than with conventional methods. Not only is there a lower dissipated heat loss on account of the reduced exhaust gas temperature, but the piston also needs to expend less energy in expelling the exhaust gas since due to the more complete relaxation there is lower gas back pressure, or exhaust gas residual pressure to be overcome during expulsion. In addition, the exhaust noise is considerably reduced, owing to the greater expansion of the gases prior to expulsion.

Additional measures for reducing the desired charge quantity, independently of the power control, can consist of producing additional negative pressure with the charging movement of the piston which enlarges the combustion chamber, and this is essentially confined just to the combustion chamber. Therefore measures are taken here to check the flow of the gaseous component into the combustion chamber, these measures being applied directly in the region of the inlet port of the same in order to confine the additional negative pressure to just

the combustion chamber. Correspondingly, these are measures that differ from the usual measures generally provided for the power control, influencing the charge quantity for example by means of a throttle device such as carburator throttle valves or injection systems which are disposed in the path of the gas in a large distance away from the inlet port of the combustion chamber. With the method according to the invention, additional negative pressure in the combustion chamber reducing the charge quantity can be produced by closing a blocking component which is disposed in the region of the inlet port. With an engine with control components for controlling the gas exchange according to the working cycle, in particular with a 4-stroke engine, the inlet valve allocated here to the inlet port can be used as the blocking component in order to produce the additional negative pressure, the inlet valve being controlled such that it remains closed for a considerable proportion of the charging movement of the piston which enlarges the combustion chamber.

Instead of a blocking device provided in the region of the inlet port, for example an inlet valve, the negative pressure can also be produced by means of a throttle device disposed in the gas line closely in front of the inlet port of the combustion chamber. In this way a controllable throttle device can be used, the throttle effect of which can for example be controlled dependent upon the number of revolutions. However, the use of a blocking component, for example an inlet valve, to produce the additional negative pressure which limits the charge quantity on the charging movement of the piston has the advantage with respect to an inlet throttle however that the work expended by this against the negative pressure produced upon the movement of the piston enlarging the combustion chamber is substantially recovered in the subsequent compression movement of the piston, since with the closed blocking component, the negative pressure in the combustion chamber has an impellent effect upon the compression movement of the piston until this previously established negative pressure is dispelled again in the course of the compression movement.

Instead of producing additional negative pressure in the combustion chamber on the charging movement of the piston, steps can be taken to reduce the

charge quantity such that a proportion of the gaseous first component, e.g. air, is blown off from the combustion chamber during the compression movement of the piston. With Otto injection engines operating according to the four-stroke principle or Diesel engines, the blowing off of the air can be implemented via the outlet valve, which is opened for a suitable length of time during the compression movement of the piston, and then closed again before the fuel is injected. With two-stroke injection engines an additional blow-off valve can be used for this purpose.

The essential point to note is that the measures envisaged by the method according to the invention for limiting the charge quantity can be used in conjunction with the previously conventional methods for improving the efficiency. Thus for example one can additionally achieve improvements in thermal efficiency by utilising components with a higher thermal capacity. Likewise, the principle of improved efficiency by means of the highest possible compression can be realized without difficulty by choosing the size of the compression chamber in relation to the cylinder capacity such that with the reduced charging envisaged by the invention, the desired final compression pressure is produced. It is evident that the compression chamber charge which is reduced by the method according to the invention will in itself mean a reduction in the performance of the internal combustion engine. However, due to the greatly increased efficiency of the method, this loss in performance is not particularly serious and can in any case be compensated for by an increase in the cylinder capacity.

A piston internal combustion engine suitable for implementing the method with a device provided for controlling the engine power for influencing the charge quantity of the gaseous first component of the mixture of materials which can be supplied to the combustion chamber upon the charging movement of the piston, is characterized according to the invention by a limiting device substantially reducing the charge quantity independently of the power control.

In the following, the invention is described in detail by means of the examples of embodiments shown in the drawings.

Figs. 1 and 2 show diagrams of the working cycle of a four-stroke internal combustion method according to the prior art and according to an example of an embodiment of the method according to the invention;

Fig 3 shows a vertical section of a four-stroke Otto engine extending in the region of the inlet valve, drawn in a highly schematically simplified manner, for the application of the method according to the invention;

Fig. 4 shows a section, similar to Fig. 3, of a four-stroke Otto engine, for implementing a modified example of an embodiment of the method, and

Fig. 5 shows a vertical section, drawn in a highly schematically simplified manner, of a two-stroke Otto engine for fuel [or petrol] injection, which is provided for implementing an example of an embodiment of the method according to the invention.

Figs. 1 and 2 show a crankshaft (11) of a four-stroke internal combustion engine, the crank (6) of which is linked via a con-rod (7) to the piston (15) of a cylinder (8) and rotates, when the engine is running, in the direction of the arrow (13). The cylinder (8) has an inlet valve (19) and an outlet valve (20) which are opened by the cam (not shown) of a camshaft (not shown either) provided with respect to the valve control that rotates during operation against the force of the valve springs (not shown in Figs. 1 and 2).

The angular positions of the crank (6) are indicated on a spiral line (17). The successive positions adopted by the crank during the approximately two rotations in the direction of the arrow (13) are given as follows:

EÖ	=	Inlet valve (19) opens
OT	=	Top dead center (TDC) of the piston (15)
UT	=	Bottom dead center (BDC) of the piston (15)
ES	=	Inlet valve (19) closes
ZZ	=	Ignition of the compressed gas mixture inside the cylinder (8)
AÖ	=	Outlet valve (20) opens
AS	=	Outlet valve (20) closes

The working cycle begins with the opening of the inlet valve (19) when the crank position is that marked EÖ. With the outlet valve (20) closed, with the following rotational movement of the crankshaft (11) in the direction of the arrow (13), when the piston (15) moves downwards after passing the top piston dead center OT, a quantity of gas is supplied to the combustion chamber (21) through the open inlet valve (19). With the conventional method shown in Fig. 1, the inlet valve (19) remains open until the rotational position ES of the crankshaft (6) of between 35° and 45° past the bottom dead center UT is reached. With the inlet valve (19) and outlet valve (20) both closed, the content of the combustion chamber is now compressed by the movement of the piston (15), and then ignited at ignition position ZZ shortly before the top dead center is reached. During the working stroke which now follows, in the course of which the piston (15) moves from the top dead center OT towards the bottom dead center UT, both valves (19) and (20) remain closed until the outlet valve (20) opens at the position AÖ, approximately 45° before reaching the bottom dead center UT. The outlet valve (20) remains open for the subsequent expulsion of the burnt down content of the combustion chamber (21), until the piston (15) has again passed the top dead center OT and the crank position AS is reached. The control timings used in the conventional method for the valves 19 and 20, as marked in Fig. 1, can be found for example in the *"Lueger" Lexikon der Technik,* (4th Ed. Vol. 7, p. 517). Fig. 1 shows the piston (15) during the charging movement, the crank (6) having reached a rotational position of approximately 120° past OT. As indicated by a broken line (23), this position is about halfway between the open position EÖ and the closed position ES of the

inlet valve (19) so that the charging process will continue with the further movement of the piston (15) to the bottom dead center UT and the aim, in the conventional method, of achieving the best possible charging of the combustion chamber (21) is achieved.

The method according to the invention differs from the conventional method, as already mentioned, in that it operates with a reduced charging of the combustion chamber (21). Fig. 2 shows an example of an embodiment of the method according to the invention, with which the reduction in the charge quantity is achieved in that the inlet valve (19), which for the charging process with the example illustrated is opened at the same crank position EÖ as with the conventional method, is closed substantially earlier than with the conventional method. As can be seen from Fig. 2, the closure point marked ES is at approximately 60° after the top dead center OT. As indicated by the broken line (23) in Fig. 2, with the rotational position of the crank (6), the closure point ES has already been passed, i.e. the inlet valve (19) is already closed, so that with the further movement of the piston (15) in the combustion chamber (21) towards the bottom dead center UT, no increase in the charge quantity is produced, but only additional negative pressure. This negative pressure pulls the piston (15) upwards after passing the bottom dead center UT, i.e. the energy expended by the piston (15) in order to produce the additional negative pressure, apart from the losses, is recovered at the start of the compression stroke. Thus the compression stroke of the piston (15) begins initially with the break down of the additional negative pressure which was previously present, and then continues by establishing the compression pressure. The volume of the compression space in the combustion chamber (21) is chosen in relation to the cylinder capacity in such a way that, although the compression stroke begins with negative pressure, by the time that top dead center OT is reached, the desired final compression pressure has been attained. As with the conventional method, ignition follows shortly before top dead center OT is reached, at the ignition point indicated by ZZ. In the ensuing combustion it follows that a considerably reduced charge quantity is burned in relation to the cylinder capacity, with the result that a far stronger expansion is achieved within

the combustion chamber (21), and hence greatly improved energy exploitation by comparison with the known method. Because the more strongly decompressed exhaust gas can be more easily expelled after combustion with the method according to the invention, the opening point AÖ for the outlet valve can in certain cases with the method according to the invention be moved closer to the bottom dead center position UT than with the known methods. With the method according to the invention, as with conventional methods, the most suitable valve timings for any given application can be precisely determined by trials as are usually carried out for achieving optimum engine performance.

Instead of producing the additional negative pressure at the end of the charging stroke, as illustrated in Fig. 2, where the inlet valve is opened in the region of top dead center OT and then closed long before bottom dead center UT is reached, the additional negative pressure could be produced by delaying the opening of the inlet valve (19). Indeed, any section between the top dead center OT and the bottom dead center UT can be provided as a shortened opening region of the inlet valve (19) with respect to the prior art if tests should show that a particular region between the points OT and UT are particularly advantageous for a given engine.

Fig. 3 shows a four-stroke Otto engine with which the mixture of materials is ignited in the combustion chamber (21) by means of a spark plug (31) for the combustion. Of the valve control, just one inlet cam (33) allocated to the inlet valve (19) is shown which is disposed on a camshaft which rotates in the usual way at half the number of revolutions of the crankshaft (11). In the example shown in Fig. 3, as with the example in Fig. 2, the reduced charging of the combustion chamber (21) is produced by opening the inlet valve (19) only briefly during the charging stroke. For this purpose, the cam (33) is provided with a relatively sharp cam profile (35) which with the direction of rotation of the crankshaft (11) indicated by the arrow (13) and the direction of rotation of the cam (33) indicated by an arrow (37), has already released the valve end (39) at the rotational position of the crank (6) indicated, namely 90° past OT, so that

the inlet valve (19) has already closed again at this point due to the effect of its valve spring (41). During the further charging stroke of the piston (15), the additional negative pressure in the combustion chamber (21) is therefore produced in the desired manner.

Fig. 3 shows with the dot and dash line (43) as an alternative measure for producing the additional negative pressure in the combustion chamber (21) during the charging movement of the piston (15), a narrowing provided on the inlet port (43) which, as a throttling device, produces negative pressure which reduces the charge during the charging stroke of the piston (15), even when the inlet valve (19) is open. With this modified example of an embodiment, indicated by the dot and dash line, one can therefore also operate with the usual control timings shown in Fig. 1, the increased negative pressure therefore being produced exclusively by the throttling effect of the narrowing (43). Instead of the sharp profile of the cam (33) indicated with (35), a normal cam with the usual profile can correspondingly be used to control the inlet valve (19).

Fig. 4 shows an example of an embodiment that in principle corresponds to the example of an embodiment suggested by the dashed line in Fig. 3. The additional negative pressure reducing the charge quantity in the combustion chamber (21) is therefore achieved not by selecting the appropriate valve timings of the inlet valve (19), but by means of an additional throttle device in the form of a throttle valve (45) which is disposed in the region of the inlet opening of the combustion chamber (21), so that the increased negative pressure produced by the charging stroke is essentially confined to the region of the combustion chamber (21). By shifting the throttle valve (45) in the direction of its valve shaft, the size of the opening can be adjusted, i.e. the throttling effect is controllable. Thus the extent of the additional negative pressure, and so also the degree of restriction of the charge quantity, can be adjusted to the desired value, if necessary optimized dependent upon the number of revolutions. In all the examples of embodiments with which the additional negative pressure is produced, not by selecting the control timings of the inlet valve (19) but by means of a throttle device at the inlet port, a normal

inlet cam (47) with the usual cam profile can be used instead of the sharp cam (33) from Fig. 3.

The throttle valve (45) shown in Fig. 4 as a poppet valve, could be replaced by a rotary valve or similar controllable blocking component. Alternatively, the inlet valve (19) itself could be used as a throttle device by using an inlet cam which only produces a very small valve stroke only producing a very limited inlet port, and this results in a corresponding throttling effect.

With internal combustion engines with which pure air is compressed during the compression stroke and the fuel serving as the energy source is injected into the compressed air, i.e. with two-stroke or four-stroke Otto engines with direct petrol injection into the combustion chamber and with two-stroke and four-stroke Diesel engines, as a measure for limiting the charge quantity during the compression stroke of the piston, a proportion of the air can be blown off from the combustion chamber (21). Fig. 5 shows an example of an embodiment of a two-stroke Otto engine for direct petrol injection into the combustion chamber (21) by means of an injection nozzle (51). Here, a rotary valve (53) is provided as the blow-off valve, the rotational position of which can be controlled by the crankshaft (11) dependent upon the working cycle. The rotary valve (53) opens out into the combustion chamber (21) with a blow-off slit (55) at a point above the aperture of the overflow duct (57) (the inlet slits and outlet slits are not indicated in Fig. 5). During part of the compression stroke of the piston (15), the slit (55) is opened by the piston (15) so that, with the rotary valve (53) open, air is blown off. Before the piston (15) comes close to top dead center, the piston shuts off the slit (55) so that the remaining air in the combustion chamber (21) is compressed during the remainder of the piston movement. Fuel is then injected into the compressed air through the nozzle (51) and ignited by the spark plug (31). Since the closure of the blow-off slit (55) is controlled by the piston itself, there is no need to pay any particular attention to the adjustment of the closure time for the rotary valve (53).

In engines compressing fuel-free air with a controlled outlet valve, i.e. with four-stroke Otto injection engines or four-stroke Diesel engines, the outlet valve itself can be provided as the blow-off valve that is opened for a part of the compression stroke. In such examples of embodiments, the outlet cam of the valve control is provided with a second profile which has a similarly pointed form to the profile (35) of the inlet cam (33) in Fig. 3, in order to open the outlet valve for a relatively short time during the compression stroke so that just enough air is blown off in order to achieve the desired reduction in charge quantity. Otherwise the same control timings can be used as in the conventional methods, for example therefore the control times shown in Fig. 1, the outlet valve (20) only being additionally opened and closed again during the compression stroke between bottom dead center UT and top dead center OT of the piston.

- 15 / Patent Claims -